Lessons Learned from Independent Technical Reviews of U.S. Department of Energy Low-Level Radioactive Waste Landfills/Disposal Facilities - 9056

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ABSTRACT

This paper describes the lessons learned from a series of independent technical reviews (ITRs) of waste management operations conducted at existing and proposed low-level radioactive waste landfills/disposal facilities at U.S. Department of Energy (DOE) sites. The evaluated waste disposal programs include those at Hanford, Idaho, Savannah River Site, Oak Ridge, Portsmouth, Paducah, and the Nevada Test Site. Based on these evaluations, cost-effective lessons learned were identified to improve reliability and effectiveness of DOE on-site disposal facilities. Key recommendations covered a wide range of issues, including the following: complex-wide applied research effort is needed to evaluate settlement behavior of DOE wastes and how they may affect cover performance; there is a need for unbiased assessment of relevance of liners for different climates and wastes to evaluate where and when liners should be used; there is a need to develop information to demonstrate attenuation capability of modern liner materials and to understand the attenuation capability of liners during performance assessment; a review of historical data on demolition volumes and logistics from past DOE projects can provide valuable insight that can be helpful in planning capacity of future on-site disposal facilities; and operating procedures need to be reviewed and updated on a regular basis so that procedures remain consistent with changes in requirements and take advantage of improvements in technology.

The complex-wide independent reviews have assisted DOE sites in considering lessons learned regarding common technical, regulatory, and management issues. Facility management and their operating contractors have begun implementing the applicable recommendations within the context of the DOE Order 435.1, Radioactive Waste Management.

INTRODUCTION

Between March 2007 and October 2008, the U.S. Department of Energy (DOE) conducted technical and management reviews of selected low-level radioactive waste (LLRW) disposal operations at its facilities. The reviews were conducted by an independent technical review (ITR) team (Craig H. Benson – University of Washington, William H. Albright – Desert Research Institute, David P. Ray – US Army

Corps of Engineers, and John Smegal – Legin Group) who were supported in their efforts by numerous DOE and contractor staff, both at headquarters and across the DOE complex.

The ITR project began when significant operational irregularities were identified at the Hanford waste disposal facility. These irregularities were initially identified in May of 2006 when an unknown event affected the pumps that were designed to operate automatically when the level of leachate exceeded prescribed settings. An extensive investigation in response to this event also revealed that some of the waste compaction test data did not correspond to the records of entry into the contaminated area where compaction tests were performed. When the technician who was responsible for taking these tests was confronted with this discrepancy, he confessed to having not performed the compaction tests and indicated that he had fabricated the test data since June of 2005. [1]

DOE and the U.S. Environmental Protection Agency (EPA) were notified of the deficiencies and the facility was placed in a standby mode. Shortly thereafter, EPA imposed conditions for a limited restart and, with the consent of EPA, limited waste placement operations were resumed in an area of the facility that had not yet been used.

Based on its review, the ITR team concluded that the contractor had taken corrective actions that would greatly reduce the probability of data falsification in the future. The team also concluded that the proposed leachate management plan would minimize the likelihood of unrecognized pumping system failures and excessive leachate depth. Lastly, the ITR team recommended that the facility adopt new technologies that would allow for a performance-based approach to compaction – validated by a proposed waste placement and settlement monitoring test. Soon after the review was completed, EPA allowed the facility to return to full-scale operations. [2]

Based, in part, on the success of the Hanford review, DOE's Office of Environmental Management (EM) sponsored a series of follow-on reviews at other LLRW management facilities. The subsequent reviews were conducted of existing and proposed operations at Idaho, Oak Ridge, Portsmouth, Paducah, the Nevada Test Site, and the Savannah River Site. The goal of the reviews was to provide an independent perspective on the disposal operations that could identify factors that might hinder meeting long-term performance goals or improve the effectiveness of operations. The team considered technical, regulatory, and management issues, and attempted to provide advice and recommendations helpful to DOE sites and HQ.

FACILITY DESCRIPTIONS

The facilities reviewed by the ITR team were exceptionally diverse, located across the county in arid and wet climates, influenced by different geological and hydro-geological conditions, and existing in various stages of development – from conceptual design to fully operational. Brief summaries of the facilities are presented below:

- **Hanford Environmental Restoration Disposal Facility (ERDF)** -- The ERDF is a large-scale disposal facility operated by the DOE to receive waste from Hanford cleanup activities. Currently, eight disposal cells comprise the ERDF, with two more cells being planned for construction. Approximately 6.8 million tons of waste, with approximately 39,000 Ci of radioactivity, has been placed in the ERDF. The cells are each 152 m square at the bottom, 21 m deep and over 304 m wide at the surface. The cells are doubled-lined with a Resource Conservation and Recovery Act (RCRA) Subtitle C-type liner and have a leachate collection system. An interim cover has been placed over filled portions of the first two cells. After the ERDF is filled, a final cover will be placed over the entire facility to provide isolation from humans and other biota at the surface and to limit percolation of water into the entombed waste. The design of the final cover has not yet been completed. [3, 4, 5]

- **Idaho CERCLA Disposal Facility (ICDF)** – The ICDF is authorized by EPA and the Idaho Department of Environmental Quality for the disposal of LLRW and mixed low-level waste generated from remedial activities at the Idaho National Laboratory (INL). Components of the ICDF include a landfill that is used for disposal of solid waste, an evaporation pond that is used to manage leachate from the landfill and other aqueous wastes (8.3 million L capacity), and a staging and treatment facility. The ICDF has a disposal capacity of approximately 390,000 m^3 and currently contains approximately 170,000 m^3 of waste. The landfill is 213 m x 244 m at ground surface and is approximately 12 m deep. The facility includes a double composite liner system, a leachate collection system, and a leak detection system. After the ICDF landfill is filled, an engineered final cover will be installed that consists of a store-and-release layer overlying a composite barrier system. [6]

- **Environmental Management Waste Management Facility (EMWMF)** – The EMWMF is a land disposal facility authorized by EPA and the Tennessee Department of Environment and Conservation for disposal of wastes generated by environmental restoration activities at the Oak Ridge Reservation. LLRW, hazardous waste, and Toxic Substances Control Act wastes are approved for disposal in the EMWMF. The landfill consists of five cells with a waste depth of up to 23 m. Cells 1-4 have a combined capacity of 920,000 m^3. Cell 5, to be constructed in the future, will increase the total capacity to 1,300,000 m^3. All of the cells are lined with a state-of-the-art double liner system consisting of a lower composite liner and an upper geomembrane liner. After the EMWMF is filled, an engineered final cover will be installed that is intended to limit percolation to less than 10 mm/yr. A multi-layer cover design has been proposed. [7]

- **Paducah Gaseous Diffusion Plant (PGDP) On-site Disposal Facility (OSDF)** – The PGDP is an active uranium enrichment facility that is owned by DOE. Uranium enrichment facilities at PGDP are leased to and operated by the United States Enrichment Corporation. In 1994, PGDP was placed on the National Priorities List. Consequently, DOE is required to cleanup PGDP in accordance with CERCLA. A Federal Facilities Agreement (FFA) was created in 1998 to define the regulatory framework for remedial activities at PGDP. DOE is evaluating alternatives to dispose of wastes generated from the remedial activities at PGDP. One option is to construct an OSDF meeting the applicable or relevant and appropriate requirements (ARARs) as defined by CERCLA. In effect, this will require that the OSDF have the characteristics of a RCRA Subtitle C landfill, while also meeting the requirements of DOE Order 435.1. [8]

- **Portsmouth Gaseous Diffusion Plant On-Site Waste Disposal Facility (OSWDF)** – As one of the options, DOE is considering that some wastes generated from decontamination and decommissioning activities at Portsmouth be disposed off in an on-site landfill referred to as the OSWDF. The OSWDF would be comprised of 10 cells. Each cell would be lined with a state-of-the-art double liner system consisting of two composite liners. Leachate on the upper liner would be managed using a leachate collection system. Liquid migrating through the primary liner would be removed by a secondary leachate collection system, which is often referred to as a 'leak detection system' in practice. An engineered final cover would be installed over the waste when the OSWDF is closed. A multi-layer cover design would be employed that relies on a composite barrier overlain by a drainage layer, a biointrusion layer, and a vegetated surface layer. The design is analogous to the final cover used for the OSDF at Fernald and the EMWMF at Oak Ridge. [9]

- **Nevada Test Site (NTS) Areas 3 and 5** – NTS is part of the Nevada Site Office for the National Nuclear Security Administration. NTS extends over approximately 356,000 ha straddling the Great Basin and Mohave deserts, and is located approximately 105 km north of Las Vegas. Radioactively contaminated materials from the NTS, other DOE facilities, and other federal agencies are disposed at NTS at two LLRW management sites: Area 3 and Area 5. Disposal operations at Area 3 have been discontinued since 2006, but the facility is available for future disposal. Area 5 is still operating and will be expanded to accept future wastes. LLRW and mixed waste are disposed in Area 5 in shallow (3-15 m deep) unlined trenches and pits. Mixed waste disposal activities are conducted in accordance with a state-issues permit. More than 400,000 m^3 of LLRW and 8,600 m^3 of mixed waste have been disposed in the existing (65 ha) developed area. Nearly 3 million m^3 of capacity remains within the 300 ha footprint of Area 5. A monolayer cover design is proposed for both Areas. [10]

- **Savannah River Site (SRS)** – Disposal operations have been conducted at the SRS for more than 50 years. The active disposal areas are located in the E Area, which is near the center of SRS. Wastes that are being managed include LLRW, transuranic, hazardous, TSCA waste, and mixed wastes. LLRW is the only waste type disposed of onsite. Except for wastes associated with naval reactors, all of the wastes disposed at SRS are from 17 on-site programs. Approximately, 19,000 m^3 of LLRW has been disposed annually at SRS between 2002 and 2007. Approximately 10,000 m^3 of LLRW was disposed in 2008 and approximately 9,000 m^3 is projected to be disposed of in 2009. Wastes are disposed in unlined slit trenches, unlined engineered trenches, low activity waste vaults, and intermediate level vaults in the E-Area. Some of the LLRWs are grouted in place to provide isolation. All of the wastes ultimately will be covered with a cap that includes a hydraulic barrier intended to limit the amount of precipitation entering the waste. [11]

LINES OF INQUIRY

Upon completing the review of the ERDF at Hanford, there were three basic lines of inquiry that the ITR team applied at all the subsequent operating waste containment facilities. These lines of inquiry are as follows:

- Do any issues exist with the landfill/disposal facility design, operations, and management that could impact its ability to meet performance objectives? Are there potential issues in the landfill/disposal facility program that could lead to problems similar to those identified at ERDF? If yes, have preventive and mitigative measures been taken to remedy the situation?

- Are there cost-effective lessons learned from the ERDF review that may be recommended to improve reliability and effectiveness of the reviewed landfill/disposal facility operations and management?

- Are there good practices at the facility currently being reviewed that may benefit other EM sites?

The landfill/disposal facility ITR project was collaboration between the ITR team, DOE site and HQ staff, and contractor personnel. In addition to the basic lines of inquiry, these groups worked together to identify site-specific lines of inquiry. For example, for the two sites (Portsmouth and Paducah) that did not have operating disposal facilities, the team evaluated prospective siting, public involvement, and regulatory interaction issues. Other site-specific lines of inquiry assessed seismic vulnerabilities and facility design alternatives under different regulatory requirements.

LESSONS LEARNED

The lessons learned by the ITR team during the course of its review were as diverse as the sites it visited; however, there were several common themes that emerged. The team observed that the on-site disposal facilities, typically expected to function for at least 1,000 years, represent an enormous engineering objective; one that requires closer attention to engineering behavior than in conventional infrastructure projects. As practiced at many sites, the team concluded that all DOE sites should periodically review and update their operating procedures to address changes in requirements and technologies. They need to ask whether practices or technologies have changed, and in particular, whether there are methods or technologies available that can reduce cost and improve performance. The ITR team also observed that a wider use of automation can prevent human error, worker exposure, and related problems. Opportunities for increased automation include monitoring systems (e.g., leachate levels, tank levels, detection zone flows), waste placement and compaction, and waste tracking and acceptance. Any automated system also requires periodic testing to ensure consistent performance.

A review of historical data at the facilities can provide valuable insight on critical trends and inconsistencies. For example, sites should evaluate whether leachate levels are consistent or rising over time and whether compaction testing data is consistent, or even too consistent. The team also stressed the importance of effective auditing techniques to assess how such data are being generated and to minimize potential data collection problems. In addition, effective and meaningful data collection does more than measure performance; it also can be used to demonstrate competence to stakeholders at existing and new disposal sites.

Key recommendations covered a wide range of issues, including the following:

- Complex-wide applied research effort is needed to evaluate settlement behavior of DOE wastes and how they may affect cover performance. Cover settlement is one of the common issues at all DOE sites;

- Efficacy of liners for DOE wastes needs re-assessment. There is a need for unbiased assessment of relevance of liners for different climates and wastes to evaluate where and when liners should be used;

- There is a need to develop information to demonstrate attenuation capability of modern liner materials and to understand the attenuation capability of liners during performance assessment;

- A review of historical data on demolition volumes and logistics from past DOE projects can provide valuable insight that can be helpful in planning capacity of future on-site disposal facilities;

- Operating procedures need to be reviewed and updated on a regular basis so that procedures remain consistent with changes in requirements and take advantage of improvements in technology; and

- It would be helpful to share experience gained at DOE sites throughout the complex by developing ‘lessons learned’ documents and by conducting workshops and/or managing web-based information.

COMMON TECHNOLOGICAL ISSUES

The ITR team determined that there were four technological issues that applied to nearly all sites in the complex. These include:

- Waste subsidence and its impact on the long-term effectiveness of final covers over disposal sites.
- The impact of waste forecasting and characterization on the required size and operation of disposal facilities.
- Long-term performance of final covers on disposal sites, given the 1,000-year life expectancy period.
- The role of liners in CERCLA/RCRA and DOE-regulated disposal sites.

Settlement

The ITR team concluded that there needs to be a complex-wide applied research effort to evaluate settlement behavior of demolition and containerized wastes and its impacts on disposal facility performance. The scope of this research should augment previous work done by DOE in response to recommendations made by the Defense Nuclear Facilities Safety Board in the early 1990s. [12, 13] Currently, most of the methods used to predict settlement are empirically based, although more sophisticated analyses using numerical models are conducted in some cases. In nearly all cases, input to empirical or numerical models used for prediction includes parameters estimated from information in the literature pertaining to other waste forms or materials, because data describing the compressibility of DOE-type wastes is scant. Additional study is needed to determine the amount of differential settlement that covers can tolerate and to quantify settlement behavior of DOE wastes using large-scale laboratory testing, field observations, and inverse analysis. In particular, settlements induced by collapse of voids (e.g., containers or vessels) are the most problematic and difficult to predict, and require the greatest amount of attention. Potential strategies for addressing settlement (e.g., dynamic compaction, smaller cells) also need further evaluation.

Waste Forecasting and Characterization

The ITR team noted that accurate waste forecasting is one of the most critical aspects of cost-effective disposal operations and that site managers that generate waste should optimize their waste stream to the fullest extent possible. Various site-specific waste forecasting models exist within the complex that are used when making short-term and long-term decisions on budgets, volume requirements, contamination levels, waste staging, handling, and scheduling. Short-term waste forecasting has been found to be more accurate than long-term forecasting, but forecasting at both time scales is important for planning and upward reporting. Forecasting models need to be simple, but flexible enough to easily incorporate changing conditions.

Covers

While RCRA/CERCLA regulated disposal systems have prescriptive requirements for final covers, DOE regulated systems establish performance objectives for disposal sites without specifying cover-specific requirements. None of the facilities reviewed by the ITR team had fully installed their final covers, and in many cases, the proposed covers had not progressed beyond the conceptual design phase. Nonetheless, the team believes that they will prove to be the most important engineering factor affecting the long-term performance of a waste disposal facility.

The performance of covers varies over time. Theses changes are related to the type of materials used to construct the cover and are difficult to predict with models a priori. The effectiveness of all covers is influenced by the presence and effectiveness of drainage layers above the barrier layer as well as biotic and abiotic interactions with the surrounding environment. DOE sites should adopt a holistic ecological engineering approach to covers that includes traditional civil and geotechnical design along with the interaction of the cover with its surrounding environment. A cost-benefit analysis should optimize the multiple components of the disposal system relied upon to achieve compliance. The effects of subsidence and degradation of cover components should be included in the cost-benefit analysis. Predictive modeling needs to be combined with monitoring programs to validate assumptions made in performance assessments and ensure stewardship of covers that transcend generations and societal change. Another possible strategy that may be considered for ensuring an effective cover performance would be to periodically assess and monitor the cover performance during the institutional control period and perform needed repairs or even replacement, as needed, to incorporate evolving technologies.

Liners

The ITR team observed that sophisticated state-of-the-art lining systems are being used at many of the sites. In addition, high overburden stress and isolation from the environment promote long-term effectiveness. The team also noted that very conservative assumptions are being used for performance assessments and that the sites should revisit this issue to see if more realistic assumptions can be applied that account for attenuation capacity of modern barrier materials. A long track record of liner performance now exists, and shows that modern liners are very effective in controlling the discharge of liquids and the migration of contaminants. However, liners are not needed or required in all applications, and should be evaluated on a case by case basis in accordance with the appropriate regulatory and technical requirements. A formal decision framework would be useful to assess various circumstances when liners should be employed (e.g., meeting a performance goal, enhancing cover performance, addressing perception of risk, improving the ability to monitor performance).

CONCLUSIONS AND PATH FORWARD

Facility management and their operating contractors have begun implementing the recommendations of the ITR team, within the context of DOE Order 435.1, Radioactive Waste Management. DOE intends to consider formalization of the communities of practice concept and the development of best practices to share information across the DOE complex.

In October 2008, DOE organized a landfill/disposal facility technology development workshop that brought together a wide range of experts – both practitioners and theorists – in the waste containment field. Attendees included representatives from academia, DOE sites and HQ, other federal agencies, as well as the private sector. The intent of the workshop was to discuss the four key technological issues presented above – settlement, waste forecasting, covers, and liner performance – and to identify future research and technological development opportunities. The following long-term research and development topics and strategies were identified to fill knowledge gaps:

- Establish a program to collect, compile, analyze, interpret, and publish settlement data from DOE sites.

- Develop techniques for reliably predicting settlement of soil-like and containerized waste forms, including parameters for design and performance prediction.

- Conduct studies to define the transport properties and life expectancy of barrier materials in LLRW environments.

- Develop probabilistic methods to address uncertainty in effectiveness of barrier materials that could be used in performance assessments.

- Conduct field studies to support site-specific and/or complex-wide characterization and field screening methods for forecasting waste streams and the potential impacts on disposal facility performance.

- Characterize the time-dependence of engineering properties of cover system components, develop in situ methods to detect such changes, and develop and validate predictive methods for performance assessments that account for time-dependent engineering properties.

The research and technology development needs identified above are likely to be phased using a prioritization process, so that sufficient resources can be allocated to issues that have the most potential for yielding optimal performance, disposal risk reduction and maximum value.

REFERENCES

1. Memorandum from T.F. Kisenwether, ERDF Operations Manager, "Falsification of Environmental Restoration Disposal Facility Compaction Logs" 373-3310/T2-03, Washington Closure Hanford, January 18, 2007.

2. C.H. BENSON, W.H. ALBRIGHT, D.P. RAY, "Evaluating Operational Issues at the Environmental Restoration Disposal Facility at Hanford" U.S. Department of Energy, Office of Environmental Management, Hanford Operations (2007a).

3. M.A. CASBON, "Design Analysis Construction of W-296 Environmental Restoration Disposal Facility, Volumes 1 and 2", BHI-00355, Bechtel Hanford Incorporated (1995).

4. "Environmental Restoration Disposal Facility (ERDF) Cells 3 and 4 Trench Liner System and Support Facilities Construction Quality Assurance Plan", 0600X-QA-G0002 Rev. 1, Bechtel Hanford Incorporated (2000).

5. "Construction Quality Assurance Plan for Environmental Restoration Disposal Facility (ERDF) Cells 5 and 6", 0600X-QA-G0003 Rev.1, Bechtel Hanford Incorporated (2005).

6. C.H. BENSON, W.H. ALBRIGHT, D.P. RAY, and J. SMEGAL, "Review of the Idaho CERCLA Disposal Facility (ICDF) at Idaho National Laboratory" U.S. Department of Energy, Office of Environmental Management, Idaho Operations (2007b).

7. C.H. BENSON, W.H. ALBRIGHT, D.P. RAY, and J. SMEGAL, "Review of the Environmental Management Waste Management Facility (EMWMF) at Oak Ridge" U.S. Department of Energy, Office of Environmental Management, Oak Ridge Operations (2008a).

8. C.H. BENSON, W.H. ALBRIGHT, D.P. RAY, and J. SMEGAL, "Review of the Proposed On□Site Disposal Facility at the Paducah Gaseous Diffusion Plant" U.S. Department of Energy, Office of Environmental Management, Ohio Operations (2008b).

9. C.H. BENSON, W.H. ALBRIGHT, D.P. RAY, and J. SMEGAL, "Review of Issues Associated with the Proposed On-Site Waste Disposal Facility (OSWDF) at Portsmouth" U.S. Department of Energy, Office of Environmental Management, Idaho Operations (2008c).

10. C.H. BENSON, W.H. ALBRIGHT, D.P. RAY, and J. SMEGAL, "Review of Disposal Practices at the Nevada Test Site" U.S. Department of Energy, Office of Environmental Management, Nevada Operations (2008d).

11. C.H. BENSON, W.H. ALBRIGHT, D.P. RAY, and J. SMEGAL, "Review of Disposal Practices at the Savannah River Site" U.S. Department of Energy, Office of Environmental Management, Savannah River Operations (2008e).

12. "Consequences of Subsidence for the Area 3 and Area 5 Radioactive Waste Management Sites, Nevada Test Site (Working Group Report)," U.S. Department of Energy, Nevada Operations Office, Waste Management Division (1998).

13. B.M. CROWE, K. LEARY, R. JACOBSON, H. BENSINGER, and M. DOLENC, "An Informal Expert Judgment Assessment of Subsidence Mitigation Options for Low-Level radioactive Waste Management Sites on the Nevada Test Site," Waste Management Symposium, 1999.